Remarks

Claims 1-70 remain in the application. Claims 71-80 have been cancelled as being drawn to a non-elected invention, but with no implication that applicants have abandoned pursuit of a patent on this invention. Claims 1, 31 and 61 have been amended to move the description of "interior support structure" from further down in the claims up to follow the first appearance of "interior support structure" in the claims, and to change "internal" to "interior" and to provide consistent antecedent basis. Claims 31 and 61 are also amended to remove inadvertently overlooked superfluous words in the first line of the claims. Claims 2, 32 and 62 are amended to add the word "interior" before "support structure."

The paragraph spanning pages 4 and 5 of the specification has been amended to insert <u>, an interior support structure, welded to a top surface of the tip plate for supporting the tip plate,</u> after the words "internal supports, basis for this amendment being found in lines 7 and 8 original claim 1.

The Examiner is urged to enter the above amendments for the following reasons:

1) They address a new rejection made under 35USC102 made by the Examiner <u>for</u>

<u>the first time in the Final Rejection</u> and applicants had no way of knowing from the First Office Action that such a rejection was going to be made. The term "interior support structure" was in the original independent claims, therefore applicants' prior amendment did not necessitate this new 35 USC 112 rejection.

2) They substantially reduce the number of claims in the application.

3) They do not require a new search.

The invention of the present claims is a bushing for receiving a molten material and for fiberizing the molten material, such as molten glass, comprising at least two opposed sidewalls and at least two opposed end walls, a tip plate having at at least 1600 orifices with or without the same number of hollow tips extending from a lower surface, the tip plate being attached to the sidewalls and end walls, the bushing having a boxlike shape having at least four interior corners, an interior support structure welded to a top surface of the tip plate for supporting the tip plate, the support structure forming at least 16 cells located between the bottom of a screen resting on, or mounted very near the top of, the top of the interior support structure. The interior support structure comprises a plurality of intersecting or crossing internal supports with angles between the intersecting supports at each intersection, the internal support structure, in cooperation with the at least one sidewall and the at least one end wall. The screen has a plurality of screen areas containing holes through the screen with a screen area above each of the at least 16 cells fromed by the internal support structure. The hole area, per unit screen area, being different in some of the screen areas than in other screen areas to achieve more uniform tip plate temperature profile. Key features of the invention are the presence of a relatively large number of separate cells beneath the screen and then locationg the screen of the invention in the bushing such that the bottom of the screen is resting on the top of the support structure, or mounted so close to the top of the support structure that the distance therebetween is less that that at which lateral flow of molten glass from one cell to one or more adjacent cells becomes significant to maintaining optimization of tip plate temperature profile, or is resting on the top of a conventional screen that is resting on the top of the support structure. The bushings of the invention advance the art by

providing much better control and uniformity of temperature of the molten glass at the tip plate using these key features than had heretofore been possible using the bushings and teachings of the prior art which did not reflect any concern for lateral flow of molten glass beneath the screen.

Figure 11 was objected to because the numeral 104 was used to identify two different items. Proposed replacement Figure 11 attached uses 118 to identify one of the elements objected to and the number 119 to identify the other element objected to. The The Replacement Sheet for Figure 11 was inadvertently not attached to the prior amendment and is attached to this Amendment. Amendment to the appropriate part of the specification correcting the element numbers in accordance with the Replacement Sheet was done in the previous amendment filed Oct. 6, 2006. Applicants believe that Figure 11 is now in compliance with the Rules for drawings and respectfully requests the Examiner to withdraw the objection to the drawings.

Claims 2, 32, and 62 stand rejected under 35USC112, first paragraph, as failing to comply with the written description requirement, the Examiner urging that the specification does not contain basis for a conventional screen lays on top of a "support structure." The description of the "interior support structure" is found in original claim 1 as comprising a plurality of intersecting or crossing internal supports with angles between the intersecting supports at each intersection. The amendment to the paragraph spanning pages 4 and 5 of the specification places the term "interior support structure" in the specification containing the description of the interior support structure. Applicant believes that the term interior support structure is described in accordance with 35USC112 in original claim 1, which is part of the specification as filed, and therefore respectfully requests the Examiner to withdraw this rejection.

Claims 1-70 stand rejected under 35USC 112, second paragraph, as being indefinite because claims 1, 31 and 61 recites the limitation "the interior support structure" in line 8, but there is insufficient antecedent basis for this limitation. If applicants understand this rejection accurately it appears that the Examiner overlooked the term "an interior support structure" in line 6 of claims 1 and 31 and line 7 of claim 61. Applicants believe that the term "the interior support structure" does have antecedent basis and respectfully requests the Examiner to withdraw this rejection.

Claims 1-70 were rejected under 35 USC 103 as being unpatentable over Coggin, Jr. in viewof Harris or Stalego and Hanna (EP '225). This rejection is traversed. The Examiner urges that Coggin teaches a bushing having a tip plate and a screen wherein the entire bottom of the screen rests on top of an interior support structure that cooperates with at least one sidewall and one end wall to form cells between the bottom of the screen and the top of the tip plate, disclosing tips or nozzles extending from a lower surface of a tip plate. Coggin's disclosed bushing that the Examiner uses in the rejection does not have a tip plate with tips or nozzles extending from a lower surface of the orifice plate 38 as apparent in different places in the specification and most particularly lines 24-26 of col. 4, where it is stated, "The undersurface of the orifice plate is planar (i.e. flat) over the entire drawing area 40 and no nozzles or tips protrude therefrom" (emphasis added). Maybe the Examiner confused the nozzles in Fig. 1A with the tips in the claimed bushing, but the nozzle 68 of Fig. 1A in Coggin refers to a bulk gas assembly having the purpose of directing a cooling gas into the array of fibers coming from the orifice plate 38, see col. 6, line 54 through col. 7, line 37. The Examiner may have misunderstood the molten glass meniscuses, the top portion of 10a in Figure 5 as tips, but that is molten glass that forms beneath each orifice in the orifice plate and is pulled into the shape of an inverted cone by the pulling of the fibers from each orifice. The type of bushing disclosed in Coggin is a completely different kind of bushing than the

claimed tip plate bushings, see the Exhibit attached containing pages 143-148, particularly the discussion of the "C" process on pages 145-148, of THE MANUFACTURING TECHNOLOGY OF CONTINUOUS GLASS FIBRES by K.L. Loewenstein, published by Elsevier, 1983. This type of flat plate bushing is not used very much, and when used, is used only for making fibers having diameters exceeding about 14 or16 microns for the reasons described by Loewenstein, i.e. that the bushing is prone to frequent flooding of the glass across the bottom of the orifice plate when a fiber breaks out, resulting in very costly down time and requiring more bushing operators than tip type bushings of the type improved by the claimed invention.

Also note from the Examples in col. 7-8 of Coggin, that the dimensions of the drawing area, the area of the orifice plate containing orifices, is at most 4.5 inches and that the internal supports (ribs) 44 are spaced on at least 0.7 inch centers. Looking at Figures 4 and 5, there would be a maximum of 6 or 7 cells in the Coggin bushing. Also note that Coggin teaches placing holes, aperatures 52 in the ribs 44 permitting "relatively unrestricted flow of molten glass through the ribs 44", permitting "glass to flow freely through the ribs and assures that the segments of the orifice plate between the ribs will be supplied with molten glass, even if a segment of the reinforcing plate should become blocked." Given this disclosure, an ordinary skilled artisan would not only not look to Coggin to improve a tip plate bushing, but would be led away from the claimed iinvention if the Coggin teachings were followed.

The Examiner urges that both Harris and Stelago teach a bushing screen having a plurality of screen areas with the hole area per unit area of screen area being different in some areas than in other screen areas and that Stelago additionally teaches that a screen area closest to each bushing corner and end wall has a hole area per unit screen area that is substantially greater than that of the screen areas that are closest to the centerline of the screen. The Examiner acknowledges that neither Harris or Stelago

teach an internal support structure attached to the tip plate, particularly an internal support structure forming at least 16 cells, but that Hanna et al teach such a support structure and that it would have been obvious to have used Hanna et al's support structure in the bushings taught by either Harris or Stalego to achieve better support for the tip plate in these bushings. This rejection, and the potential rejection that it would have been obvious to have used the teachings of either Harris or Stalego re their bushing screens to have modified the bushing screen of Hanna et al such that the hole area in some screen areas above cells is different than hole areas per screen area of other screen areas, are respectfully traversed.

Harris teaches bushings having up to 800 tips receiving solid glass marbles or other solid shapes and for melting the solid glass shapes in a melting chamber 22 in the bushing and on a baffle 24. The baffle 24 has different sized holes therethrough for the purpose of improving the temperature uniformity of the tip plate. When melting glass inside the bushing, the temperature of the molten glass varies substantially more than the molten glass coming into the bushing from a bushing leg of a melting furnace. In the Harris bushing, the bottom of the baffle 24 is located a substantial distance from the top of the tip plate 15. There is no mention or suggestion in Harris of lateral or partially lateral flow of molten glass between the baffle and the tip plate, or how to prevent such flow to achieve the maximum effect of the baffle defined by Harris. Since Hanna et al teaches at col. 8, lines 45-49, that the invention makes bushings having 1600 or more orifices perform in a substantially superior manner, it is unlikely that one of ordinary skill in the art would find it obvious to apply the very expensive support structure of Hanna et al to the 800 tip bushings taught by Harris. The support structure of Hanna et al is made from alloys of platinum and rhodium, preferably 80% Pt and 20% Rh. The prices/cost of Pt and Rh vary somewhat from time to time, but are always very expensive. For example, the current price of Pt is $1,186 per troy ounce and the cost of Rh is $5,350 per troy

ounce. Tip plate sag is not a substantial problem in an 600-800 tip bushing and would not justify so costly an internal support structure.

Even if the Examiner should reject on the basis that one of ordinary skill in the art would believe it obvious to use the teachings of Harris in the bushings taught by Hanna, there is no basis for such a conclusion and further the claimed invention would not be produced, see Figs. 2 and 2 A of Hanna et al and the figure in Harris. <u>The bushing of Harris does not receive molten material</u>, but rather receives <u>unmelted, solid pieces of glass such as marbles</u>, see col. 2, lines 67-70, and melts the solid glass while the solid pieces of glass lay on the baffle 24. As the glass melts and reaches a sufficiently low viscosity the molten glass flows through the holes in the basket 24 and down into the space above the tip plate 15. Harris states that the ends of this bushing tend to be of substantially higher temperature than intermediate portions, see lines 21-24. One of ordinary skill in the art would recognize that most or all of this situation is the result of the solid glass being introduced through only two inlets 16 that are spaced from the ends of the bushing and that the cold, solid glass therefore cools off the center portion of the bushing to a much greater extent than the ends. Thus, one of ordinary skill in the art would not look to Harris to improve a much larger bushing that receives <u>molten glass</u> material <u>already at or near fiberizing temperatures</u> and also because Harris teaches in col. 3, lines 47-59, <u>a higher open area per unit of screen at the end regions of the baffle 24 than the open area per unit of screen area in the center region of the baffle</u>, thus would clearly lead one skilled in the art <u>away from the claimed invention.</u>

Stalego, Figures 4-5, discloses a bushing for receiving molten glass from a bushing leg, but the heater strip 78 taught is corrugated or a multiple V-shaped configuration, please see col. 6, lines 35-50. These heater strip configurations taught by Stalego leave substantial distance between all of the holes in the heater strip 78 and the

top of the tip plate 15, allowing a free lateral or partially lateral flow direction of the molten glass and for mixing of the molten glass coming from the various holes of different diameter, which would frustrate the object of the claimed invention, please see the present specification at page 3, lines 25-27 and page 4, lines 12-17. Note that the rods 86 end far above the top surface of the tip plate 66. Nothing in the references cited suggests to one of ordinary skill in this art to modify the bushing of Stalego to produce the bushing structure claimed in this application or the claimed method of making the Stalego bushing. Also, the heater strips disclosed by Stalego have at most 6 areas of screen (Fig. 8) and only 3 areas of different hole size whereas the present invention provides the capability of having at least 16 screen areas capable of having different hole sizes, or other flow control parameters that will much more effectively influence the temperature of the tip plate than the 6 areas taught by Stalego because the entire screen is mounted on or near the support structure.

Also, please see Board of Appeals Decision, Appeal No. 2000-0035, re the reversal of previous rejections of bushing claims containing one or more screens like, or similar, to the screens used in the present invention as being unpatentable under 35 USC 102 as being anticipated by the same Stalego patent cited in this application, and as being unpatentable under 35 USC 103 as being obvious over the teachings of this same Stalego patent.

For these reasons Applicants believe the present claims are patentable under 35 USC 103 over Coggins in view of Harris or Stalego and Hanna et al and respectfully requests the Examiner to withdraw this rejection and to allow all of the claims.

Claims 1, 31, and 61 stand provisionally rejected on the ground of non-statutory obviousness-type double patenting as being unpatentable over claims 2 and 21 of

co-pending application No. 08/929,836 and claims 25, 27, 29 and 31 of co-pending application Serial No. 10/421,683 in view of Coggin, Jr. and Hanna et al. This rejection is traversed for the reasons given above in response to the rejection under 35USC103, applicants do not believe that the claimed invention is made obvious by the teachings of Coggin, Jr. and Hanna et al. Applicants further contend that this rejection is an improper hindsight rejection using applicants present specification as a "road map" or "template" to find references the Examiner believes teaches the various parts of the claimed invention and then improperly combining those references to obtain the invention even though one or ordinary skill in the art would not arrive at the claimed invention from the reasonable teachings of those references. For these reasons applicants believe that the claimed invention is not subject to an obviousness-type double patenting rejection and respectfully requests the Examiner to withdraw this rejection and to allow all of the claims.

Applicant's attorney believes that the amended claims above address all of the Examiner's reasons for rejection and are now in condition for allowance. If the Examiner believes that still further changes are needed, applicant's attorney invites a telephone interview to expedite the disposal of this application.

Respectfully submitted,

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Exhibit

Glass Science and Technology 6

The Manufacturing Technology of Continuous Glass Fibres

(Second, completely revised edition)

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PREFACE to the Second Edition

This book deals with continuous glass fibres used, in the for reinforcing plastics, rubber and bitumen, and for firepr curtains. These fibres are not necessarily long or continuo used in such applications but, when first manufactured, are as continuous fibres from the molten glass.

This differentiates them from discontinuous, short, or st fibres - commonly referred to as glass wool - which are almc tirely used for heat and sound insulation. Although some as of the manufacturing technology are similar to that for cont fibres, the fiberisation process is different since it aims making intertwined, short, bent lengths of glass fibre.

The technologies and markets for the two types of glass f thus differ sufficiently that they require separate treatmer further reference to glass fibres in this book will therefor glass fibres of the continuous kind.

Historically, the glass fibre industry is part of the pla and textile industries. In addition to these, it is now fir tablished also in the building components and transportatior tries. Glass fibre is a raw material for reinforcing organi mers and, sometimes, inorganic materials such as concrete, a which the general public encounters in the form of boats, pa aircraft, car components and vehicle bodies, translucent roc sheet and cladding, bitumenous roofing sheet or felt, roofir (shingles in North America), foamed PVC flooring, car tyres, in public buildings, buses, etc. One of the biggest uses is logic and printed circuit cards. As part of the textile inc proper, woven glass fibre curtain materials have establishec ket, mainly for use in public buildings because of their fi istance.

Technologically, the manufacture of glass fibres is part glass industry, but such has been the secrecy and exclusive of this new industry that most glass technologists have neve the process, and other technicians from outside - and someti side - the industry have very often seen only small sections whole on the principle of "the need to know".

The first edition, prepared 10 years ago, made a start ir

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two schools of thought concerning the broad distribution of et thicknesses. One school has the thickest metal near the zles (e.g. C = 1.25, B = 1.0, D = 0.75, E, F and I = 0.5 mm), other school thickens components E and F, e.g. to 1.0 and 0.75 respectively and sometimes also reduces D in order to develop paratively more heat at the top of the bushing. For very big hings, i.e. 800 nozzles, three feed holes have been tried, as l as placing the terminals horizontally in order to get good perature distribution across the width of the bushing. In some es a premelter heated separately has been used to separate the ting from the conditioning functions. Possibilities are united, and experimental costs high. Hence the move towards dir-melt plants.

However, for very fine fibres (7 μm diameter or less) where the luction rates are low, and where the number of nozzles per bush does not exceed 400, marble bushings have retained some posi- in the industry for sheer convenience and flexibility of op- ion.

he construction of a marble or remelt bushing proceeds simi- y to that of a direct-melt bushing except that, after attach- the basket to the bushing body, the pre-assembled bushing lid feed holes, etc., is welded into place.

In the case of direct-melt bushings, marble bushings are ed in a suitable frame - in this case usually in two parts - upported in this frame in suitable insulating refractory. g the assembly the thermocouple wires in insulating sleeves ed to the outside of the bushing frame, usually appearing at f the longer vertical surfaces of the frame about 50 mm above izzle plate.

insulating refractory must support a bushing throughout its which is, on the average, one year. It must, therefore, up to a temperature of 1250°C without shrinkage. Insulating als of this type are available in two forms, either as pieces can easily be cut by saw or similar tools to give shape that t a bushing, or in the form of a powder which, when wetted water, can be cast around the bushing. In this case care ld be taken to allow air to escape; a good practice is to cast refractory around the bushing on a vibrating table. When in-

Bushing frames should be made of non-magnetic material which does not creep significantly at 450°-500°C. Aluminium bronze 5-6 mm thick has been found satisfactory and can be cast into suitable frames. For the direct-melt bushing the frame is of one piece; for marble bushings it is in two pieces, the body and a lid which are bolted together. Frame sections near the nozzles and terminals often distort in use; however, these can be straightened after the bushing is removed at the end of its life, and the frame re-used.

V.2.4. The design of larger bushings

Economic pressure has forced the industry to maintain a constant drive to raise productivity and reduce unit costs. One aspect of this drive is the aim to produce the maximum amount of fibre from a given bushing position, i.e. the bushing and its associated equipment. Since a bushing cannot operate in isolation, a related aspect of this drive has been the development of new types of winders capable of winding rovings direct from one or more bushings, thus not only raising fibre production from a give bushing, but also eliminating a whole production stage.

In this development, the design of bushings of increased throughput has been crucial. Since the direct-roving-winder is limited in the linear drawing speed that it can provide, namely to about 1500 m/minute - which is about one half of that provided by a traditional winder - the bushing must be provided with at least twice the number of nozzles in order to maintain previous production rates.

The industry has done better than that. The problem has been eased by opting to manufacture fibres of the largest possible filament diameter, and diameters of 15 to 20 microns are now common. Bushings of 4800 nozzles are known to be in operation and those with 6000 nozzles cannot be far away. Such bushings, when producing filament of 16 microns, for example, can make rovings (for weaving and winding) of the normal 2400 tex at a rate of about 15 kg/hour.

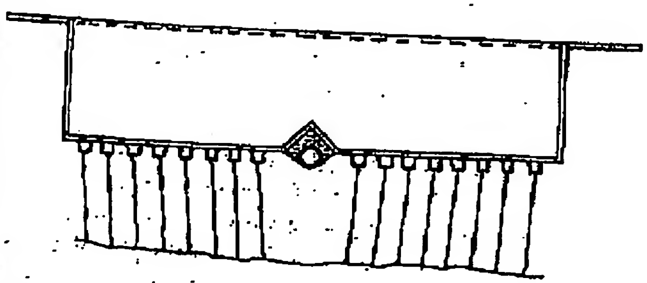
The larger throughput bushings present major design and operational problems:-

(1) the need to maintain the very large nozzle plate at a uni-

e operating temperature and under the head of glass above the zzle plate.

The first point can be covered by suitable variation in the tal thickness of various parts of the bushing coupled to major sign changes such as placing the terminals horizontally, and by ranging the inlet of the bushing and the outlet of the forehearth such a way that the glass flows in lamellar flow into the bush- g and at the temperature required for fibre forming; thus, the ergy supplied to the bushing is minimised, as is the problem of mperature variation of the nozzle plate.

The creep of bushings at elevated temperatures and under the ads normally existing cannot be eliminated. It is possible to stiffer platinum alloys in whole or in part (see Section V.2.1) t, in any case, extra mechanical stiffening internally and exter- lly becomes necessary. Fig.V/12 shows such an external support; consists of a stainless steel pipe, water cooled, located long- idinally along the centre line of a bushing with refractory ce- it between the pipe and the nozzle plate. In addition, extra ge and more stiffeners are provided internally across the width the nozzle plate.



g.V/12. - External support for large bushing consisting of a water-cooled pe located centrally and longitudinally under the nozzle plate with re- actory cement located between pipe and nozzle plate.

* The Strickland-PPG ('Microdyne') and 'C' processes

Provided that there is a supply of glass which exceeds the rate which fibre can be drawn from a given bushing, the size of the

fice plate.

When comparing the manufacturing technologies of synthetic (organic) polymer fibres with that for glass fibres, a striking difference is the size of the nozzle plate for similar production rates (in terms of volume) between what are, after all, two types of polymers. The differences lie

(1) in the pressurisation of the supply of organic polymer upstream of the spinneret;

(2) the consequent reduction in nozzle (hole) size and closer spacing that this characteristic allows;

(3) the fact that the material of which spinnerets for organic polymers are manufactured are not wetted by the liquid polymer.

In the 'Microdyne' process glass fibres are drawn using techniques derived in concept from those used for organic polymer fibres but adjusted to make them suitable for glass. The glass supply is pressurised, thus enabling the nozzle or hole diameter for a given throughput to be reduced. In this process holes were substituted for the traditional nozzles and, instead of internal nozzle diameters of $1\frac{1}{2}$ - $2\frac{1}{2}$ mm, holes of $\frac{1}{2}$ mm diameter were needed. These could be spaced so closely that, instead of the 0.1 m^2 nozzle plate area of the traditional bushing of 400 nozzles, an area of only 100 mm^2, a reduction of 1/100th, is required in this instance The bushing became very small indeed (see Fig.V/13).

Despite early promise, this process is still under development. Many reasons for problems can be imagined. Judging by the patent literature they appear to include problems in the removal of gas bubbles from the glass, a problem virtually unknown in normal E glass fibre manufacture, and engineering problems connected with the manufacture and operation of bushings, in one instance even returning to the use of nozzles, and the temperature control and heating of these miniature bushings*.

From what followed, one can also surmise that the objective may have been over-ambitious. Its successor is a process intermediate in concept. In the 'C' process the extra pressurisation of the glass supply to the bushing is abandoned and the development concentrated on making fibre forming possible from plates containing holes rather than nozzles. The reduction of the length of the cylindrical section of a nozzle to that of a hole through a plate

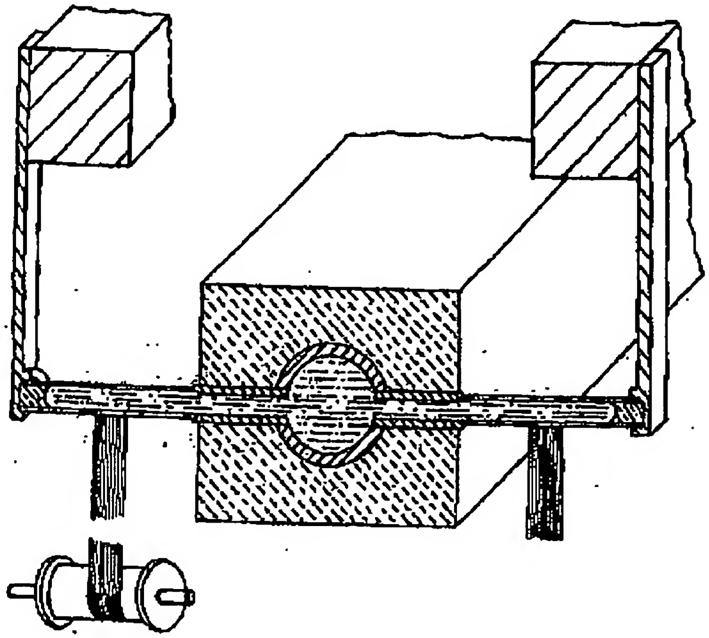


Fig. V/13. The Microdyne Process. Liquid glass under pressure is supplies into electrically-heated pipes, a section of which has been provided with very small holes where the glass is extruded and attenuated.

sely together than is the case with traditional bushings; the ing in the weight of platinum metals is about 70% (see Fig.V/14). he operating problem associated with the C process bushing is to overcome and control the tendency of the glass to wet the ice plate. In the main this is achieved by playing a jet of air onto the orifice plate from the underside, thus chilling menisci of glass and reducing the tendency for liquid glass to from one orifice to the next. A supporting technique is, as already been referred to in Section V.2.1., the use of an alloy t provides the highest possible contact angle with glass. In er to maintain the strength and creep resistance of the orifice

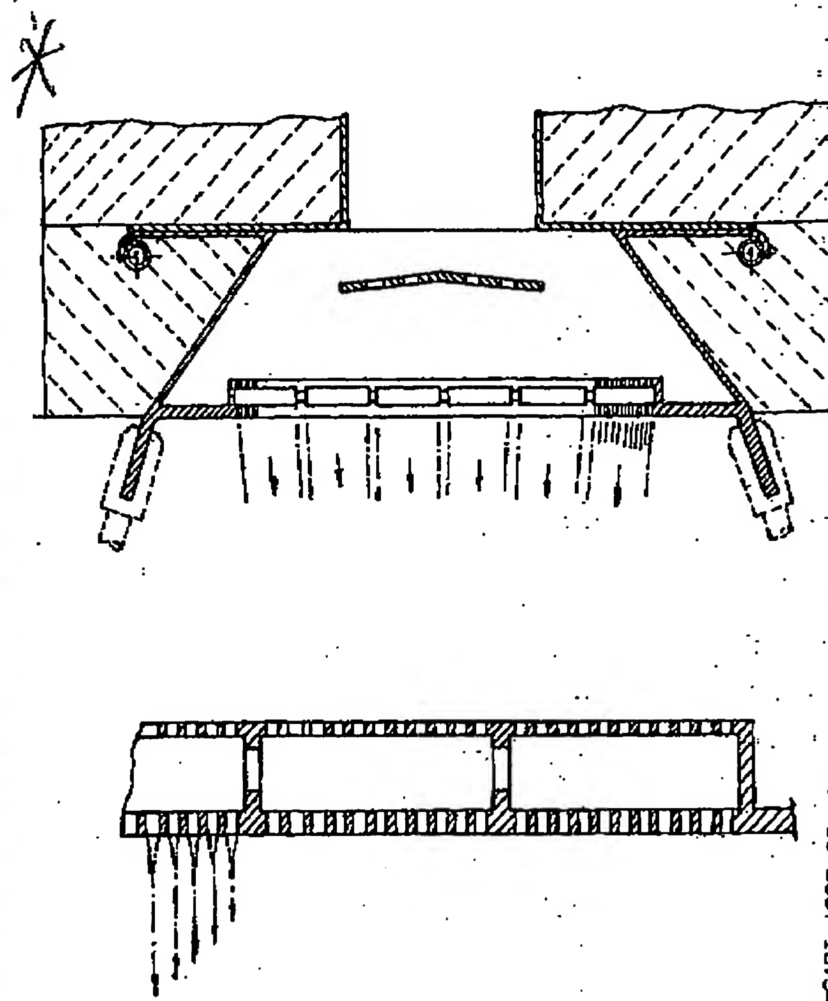


Fig.V/14. A typical bushing according to the 'C-process'. Above, a general view; below, an enlarged view of part of the orifice section. The construction shown, with a perforated plate above the orifice plate proper and connecting members between the two is designed to reduce distortion of the orifice plate. Also note ... temperature uniformity of the orifice plate is

:he normal 20% rhodium/platinum alloy; an outer surface alloy of 30% gold/20% palladium has been suggested[7].

This process, while operating and forming fibres, is very pro-luctive. In view of the large number of orifices that can be fit-ed into a comparatively small orifice plate it is particularly uitable for the manufacture of direct-wound rovings for filament inding and weaving. Further improvements in productivity have een achieved by increasing the filament diameter of the fibres rawn. It would appear that all fibre being made by the C process s of 14 micron diameter or above[8].

While progress has been very substantial, one particular problem ssociated with this process still requires solution. This problem s that if a filament breaks, the glass tends to flow from the ori-ice where the break occurred to adjacent orifices. Either other ibres can then begin to break or the glass flows into the meniscus f the adjacent orifice making the filament drawn from that orifice vice as heavy per unit length. To avoid this problem, or minimise ., first, the quality of the glass being supplied to the bushing ist be maintained at the highest level thus reducing the frequency : filament breaks; second, the operator must be quick to react to filament break because one filament break can cause adjacent fil-ent breaks and 'flooding' of the orifice plate by molten glass. flooding does occur extra air jets for cooling the orifice plate st be available and the operator has the laborious task of 'clea-ng' the orifice plate by detaching some of the glass adhering to orifice plate, and then pulling it away sufficiently fast to ove other glass adhering to the plate but leaving glass flowing : of the holes and forming fibres. It is believed that this aning operation can take 20 - 30 minutes. This need for 'in-nt' operator intervention implies rather high staffing levels. It is difficult to predict how far the C process will penetrate existing technology, bearing in mind the degree of automation ady attained for the older bushing types and the reduction in number of operators, or cost of labour per unit weight of fibre, this implies.

*

5. Nozzle shields and the stability of the fibre drawing process

ie invention of nozzle shields was a major step in increasing stability and production rates of the fibre-drawing process, as

well as a necessary step in the development and successful use of bushings fitted with very large numbers of nozzles[9, 10].

Reference has already been made to the need for achieving a stable meniscus for the efficient conversion of glass into fibre. From the point of view of the glass composition itself, a point that has become increasingly important as new compositions are be-ing considered for fibre drawing, reference has already been made in Section IV.2 to the fact that, the lower the liquidus tempera-ture of a glass the more stable it is against devitrification, i.e. crystallisation. Bearing in mind that, in the fibre drawing pro-cess, the temperature of the glass changes rapidly while it passes through the nozzle during attenuation, and that the formation of crystals must be avoided in order to maintain the fibre drawing process, it follows that, the greater the temperature difference between the nominal temperature for fibre drawing (T_f) and the liquidus temperature (T_l), the lower the risk of crystallisation occurring. In practice, a minimum difference of 50°C has been stated as necessary, with a preferred difference of 100°C; for E glass the difference is 140°C; for some of the alkali resistant glass for reinforcing cement, the values are frequently less than 140°C[11].

For a given glass composition there is a narrow temperature range within which the balancing forces of surface tension and viscosity permit the continuous drawing of fibre. If the viscos-ity is too high, i.e. the temperature too low, the tension neces-sary for drawing fibre can exceed the tensile strength of the fi-bre just formed, which will then break. If the viscosity is too low, the meniscus becomes unstable, a fact that can be observed by a "pumping" phenomenon just below the meniscus, indicating an in-termittent passing of fibre of greatly increased diameter. At some moment enough glass will arrive in the meniscus to temporar-ily raise the glass temperature to a point where surface tension becomes the dominant factor; the fibre will then break at the meniscus.

The range of viscosity of the glass suitable for fibre drawing lies in the range where $\log \eta = 2.5 - 3$.

These points cover the problems of fibre drawing stability from the technical point of view but omit those which are due to extra-neous effects, such as inclusions from raw materials or refractor-ies, dust and dirt etc.

From the economic point of view, it is clearly desirable to

Replacement Sheet

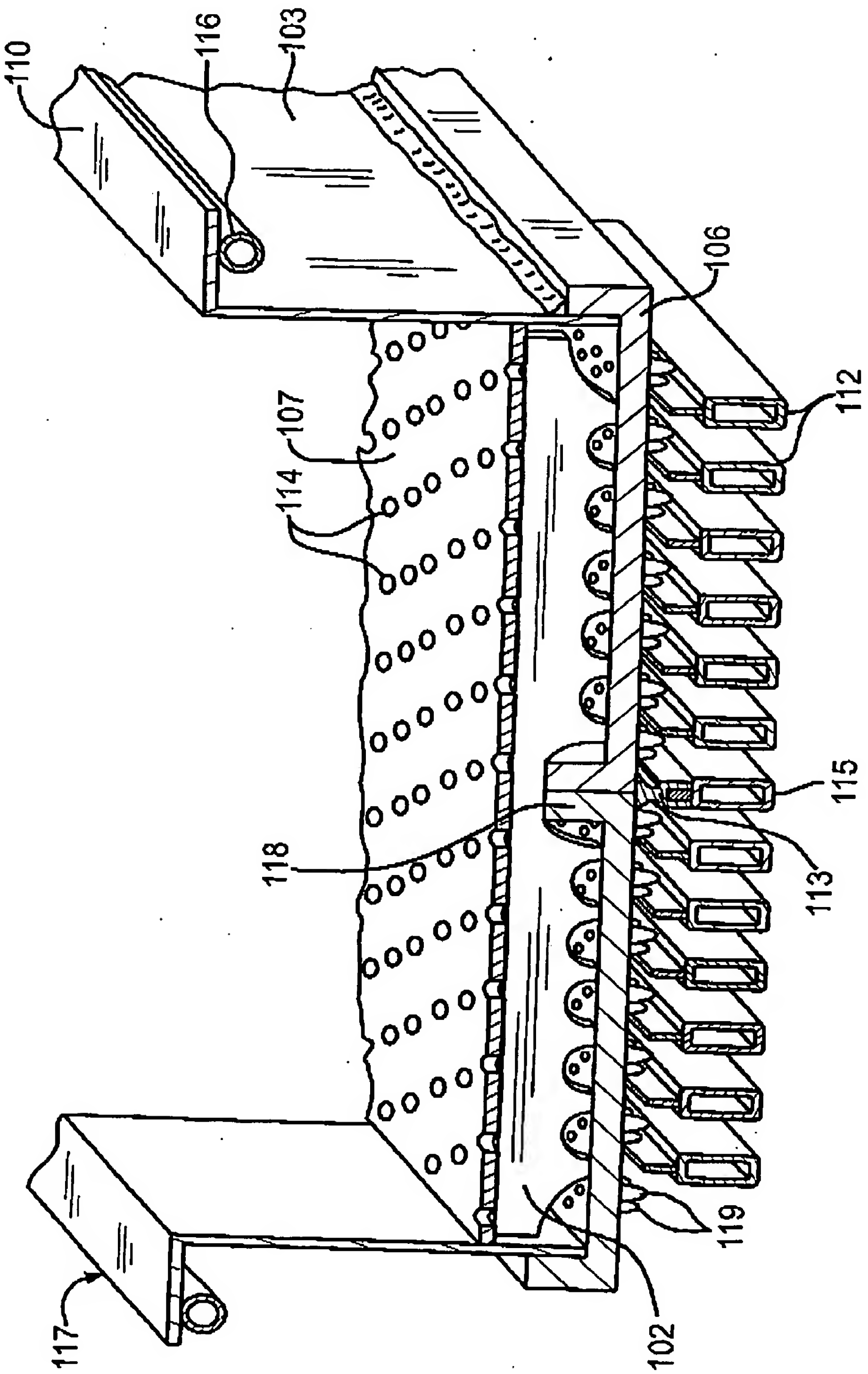


FIG. 11